Design and Study of Bio-Mass Chopper

A thesis submitted in partial fulfilment of the

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Bachelor of Technology

In

Industrial Design

By

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With sincere regards,

M. RAMESH
&
PRATIK SHUBHANKAR

ABSTRACT

A chopper for cutting/slashing down biomass material using limited manual labour. The method includes selecting and moving biomass stocks through the input area and conveying it down towards the machete, operated manually or automatically using a motor, on a conveyer belt which also runs on motor. The machete chops down the biomass to convert it into small pieces or chunks, as desired and is collected back from the output area. The length of the piece to be cut can be varied as required by varying the speed of the two motors accordingly. The chopped biomass can be used as biomass fuel bricks or to feed animals. The biomass chopper is designed with a prospect of keeping its cost low and providing a mechanism simple enough so that it can be operated by even women and children.

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1. Introduction

1.1 Origin of the Problem: Need for Design

The Bio-Mass chopper is primarily used to chop large stocks, wastes, husks, into smaller size so that they can be brought into use for a number of applications such as;

- Feeding animals: As it's difficult for animals to feed onto larger stocks, chopping helps them to easily feed onto or chew the biomass.
- To prepare Biomass fuel: The chopped wastes can be converted into biomass fuel bricks via chopping and grinding and further burning and compression process.

Fig 1.1: Biomass fuel bricks.[1]

1.2: Aim of Project

The aim of designing the biomass chopper is to increase the ease of its operation and decrease its cost, so that a large range of people can use the machine with full comfort, effectiveness and safety.

1.3: Objectives

- To make the 2D sketch of the chopping machine and its parts
- To make a 3D model of the Bio mass chopper with the help of CAD software CATIA V5 R17.
- To make a scaled physical model of the chopper
- To interpret the results and propose new design concepts and modifications considering ergonomics.

1.4: Background

1.4.1: Biomass

Biomass is biological material got from living, or as of late living life forms. It frequently alludes to plants or plant-based materials which are particularly called lignocellulosic biomass. As a vitality source, biomass can neither be utilized specifically by means of combustion to create warm, nor in a roundabout way in the wake of changing over it to different manifestations of biofuel. Transformation of biomass to biofuel can be attained to by distinctive strategies which are extensively characterized into: chemical, thermal and biochemical methods [2]

Wood remains the biggest biomass energy source to date samples incorporate forest residues, (for example, dead trees, branches and tree stumps), yard clippings, wood chips and even city strong waste. In other terms, biomass incorporates plant or creature matter that can be changed over into fibres or other industrial chemicals, including biofuels. Plant energy is being generated by corps particularly developed for utilization as fuel that offer high biomass yield

Biomass can be changed over to other usable manifestations of energy like methane gas or transportation fuels like ethanol and biodiesel. Decaying junk, and agrarian and human waste, all discharge methane gas—likewise called "landfill gas" or "biogas." Crops, for example, corn and sugar stick, can be aged to deliver the transportation fuel, ethanol.

Fig 1.2: Rice husk used as biomass [3]

The biomass can also be used for electricity generation and it varies as per region. Forest by-products for example wood residues are most common in the United States. Agricultural waste can be seen to be used extensively in Mauritius (such as sugar cane residue) and Southeast Asia (e.g., rice husks). While in UK, we can find animal husbandry residues, such as poultry litter to be common.

1.4.2: Particle size reduction.

The application of pre-processing operations, for example, particle size reduction/ grinding is basic to further enlarge the surface area of lignocellulosic biomass before densification. Particle size reduction enlarges the aggregate surface area, pore size of the material and the quantity of contact focuses for inner particle bonding while the compaction process takes place. Size reduction is a vital energy intensive unit operation key for bioenergy change procedure and densification to diminish transportation costs.

Baled agricultural biomass obtained from the field does not have great streaming qualities and may not flow effortlessly into grinders, for example, hammer mills and disc refiners. Because of this the biomass needs to be chopped with a chopper (rotational shear shredder)/ knife mill/ tub processor to oblige mass stream and uniformity of food rate. A chopper, knife cutter, or knife mill is regularly utilized for coarse size reduction (>50 mm) of stalk, straw, and grass food stocks. Knife mill apparently worked effectively for destroying scavenges under different crops and machine conditions. [4]

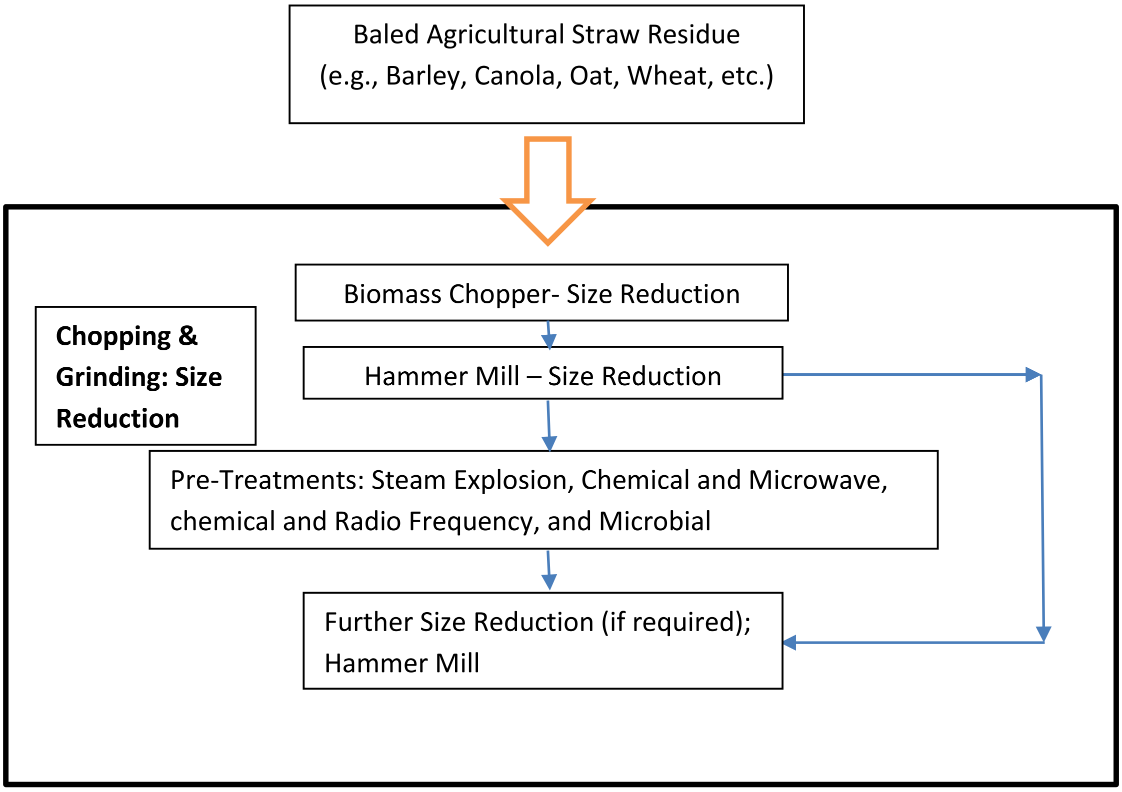

Fig 1.3: Processing steps involved in converting straw to pelletized product [4]

1.4.3: Working Principle

A Biomass chopper works on the principle, according to which a machete used for cutting the biomass is connected to a spring which exerts the force required to cut the material. The end of machete is connected to a rotating axle which can be operated manually by hand or it can be automated using a motor. The machete makes two cuts for every one rotation of the axle. The cutting mechanism is shown by the following three diagrams;

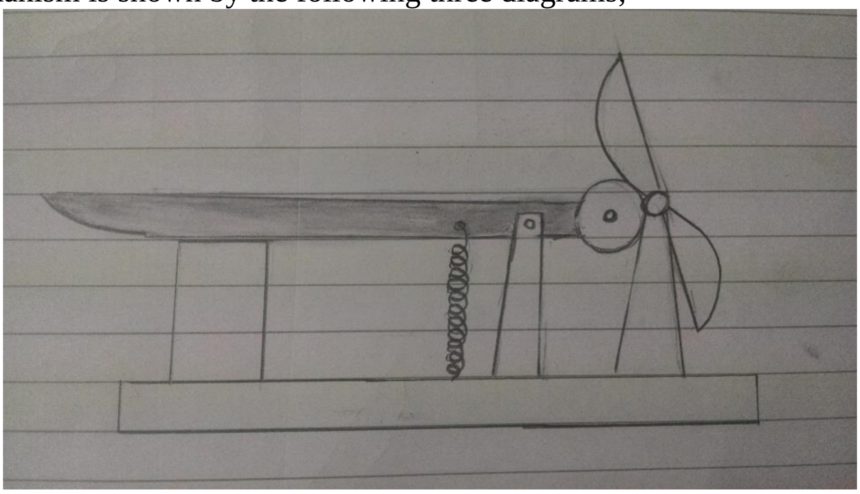

Fig1.4: Cutting mechanism 1.

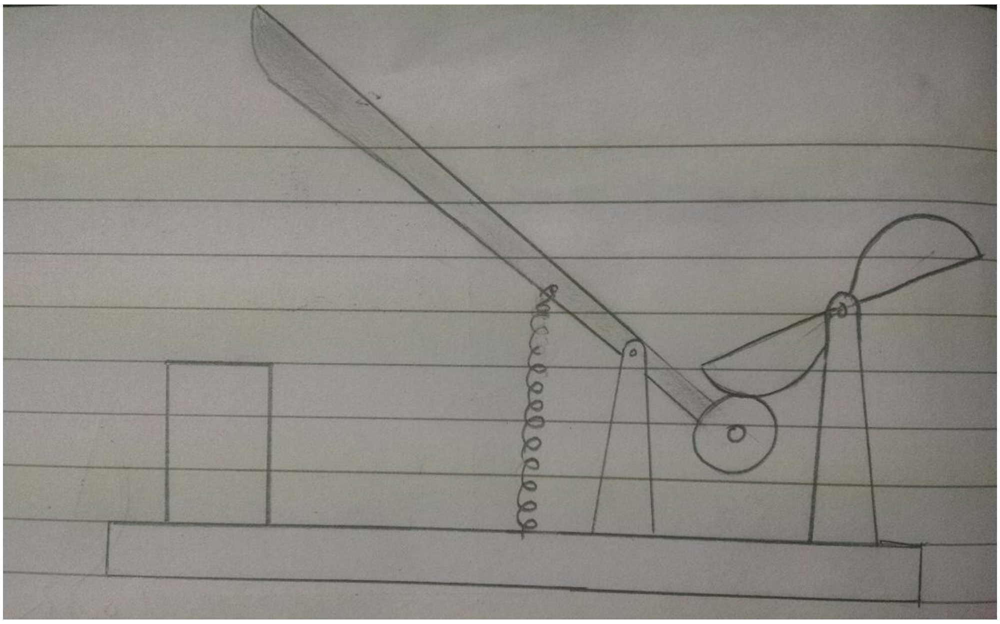

Fig1.5: Cutting mechanism 2.

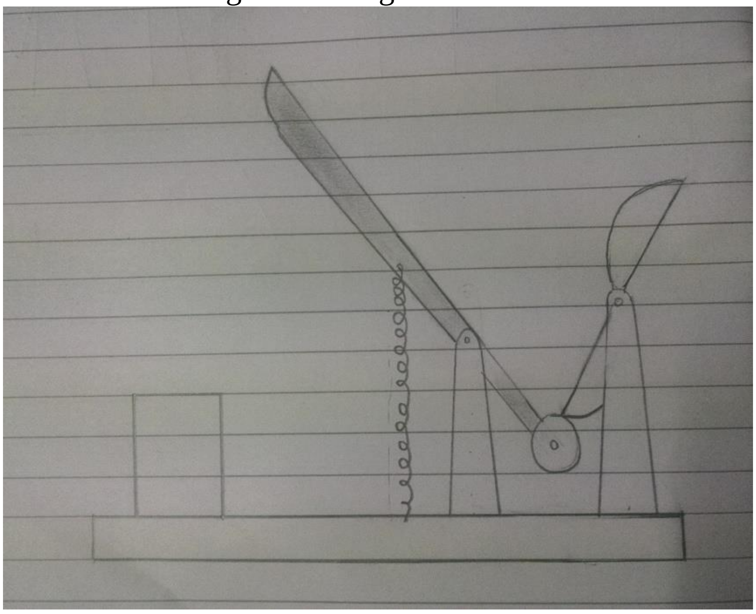

Fig1.6: Cutting mechanism 3.

The input box consist of a conveyer belt on which the input feed is kept and allowed to be moved towards the machete. The conveyer belt is operated by a motor whose speed can be varied as required. The length of cut required can be adjusted by changing the speed of the two motors operating the machete and the belt. The feed cut is then collected through the output area.

1.4.4: Raw material used as feed

There are a variety of materials that can be used as a source of input for the above purpose. Some of the most consistently used materials are;

- Agricultural waste
- Rice husk
- Bagasse
- Ground nutshells
- Corn/ Jowar tree

- Banana tree stocks.
- Oat and wheat straw
- Canola/Barely [5]

Fig 1.7: Fully grown corn tree [6]

2. Methodology

2.1 Numerical Analysis

The length of cut can be varied by changing the speed of motor of the conveyer belt taking input or of the shaft rotating the axle as per requirement of the user.
For an example;
Let us consider both motors to be of 30 r.p.m
Length of input belt as per design is: 460mm
Diameter of input shaft: 40mm

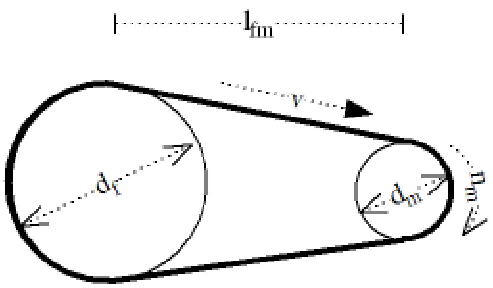

Fig 2.1: Conveyer belt calculations [7]

The velocity at which a belt travels may be expressed as

v = π*d*n / 12   (1)

where;

v = velocity of belt (mm/min)

n = velocity motor (rpm)

d = diameter shaft (mm) [7]

Now,

As per above data the axle complete 1 rev. in 2 sec. In 360 degree the machete makes two cuts. Hence it makes one cut in 180 degree or in 1 sec.

Machete: 1sec-180degree-1cut.   (2)

The input belt velocity;

v = 3.14*40*30 / 12 (1)

v = 314mm/min = 5.24 mm/sec (3)

Hence;

From (2) & (3) we have,

Length of cut = 5.24 mm

Therefore, for 30 r.p.m motors length of cut is 5.24 mm. To increase the length of cut we should decrease the motor rpm of input belt and similarly to decrease the length of cut the rpm should be increased.

Length of cut $\propto$ 1 / input belt motor r.p.m

2.2 Target Population

The product is targeted to be used by Indian rural male and female workers as well as children. The product is designed at low cost and simple mechanism, so that the rural people can use the machine with full comfort, effectiveness and safety.

2.3 Hand Sketches – Design Development

The initial sketches of the bio mass chopper was being made and then a final sketch was conceptualized and the parts were designed individually. The sketch of the machine and its important parts are shown below.

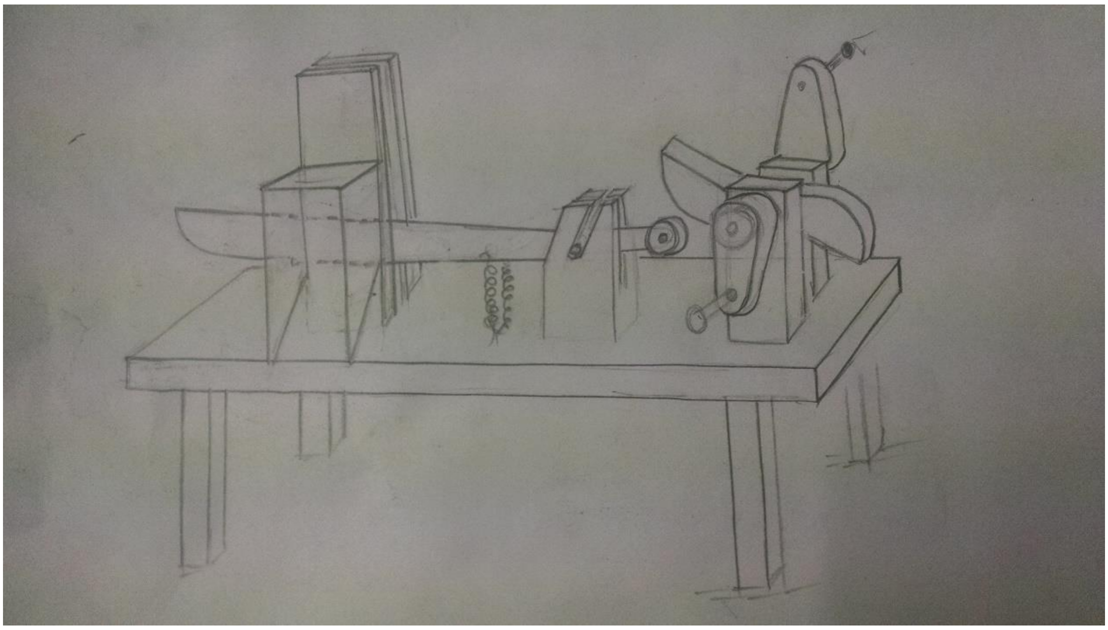

Fig 2.2: Initial sketch of the chopper set-up

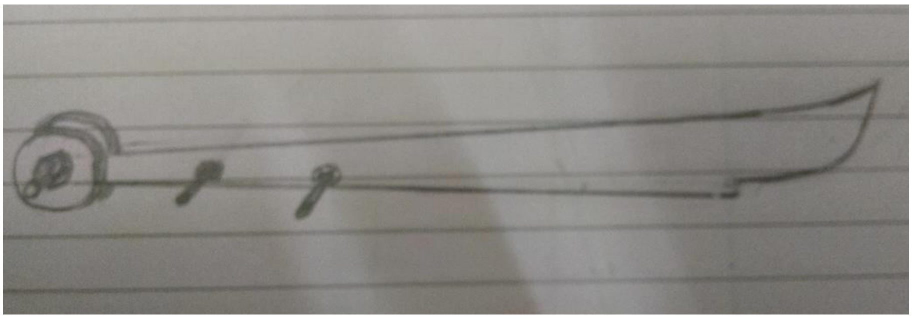

Fig2.3: Sketch of cutting machete.

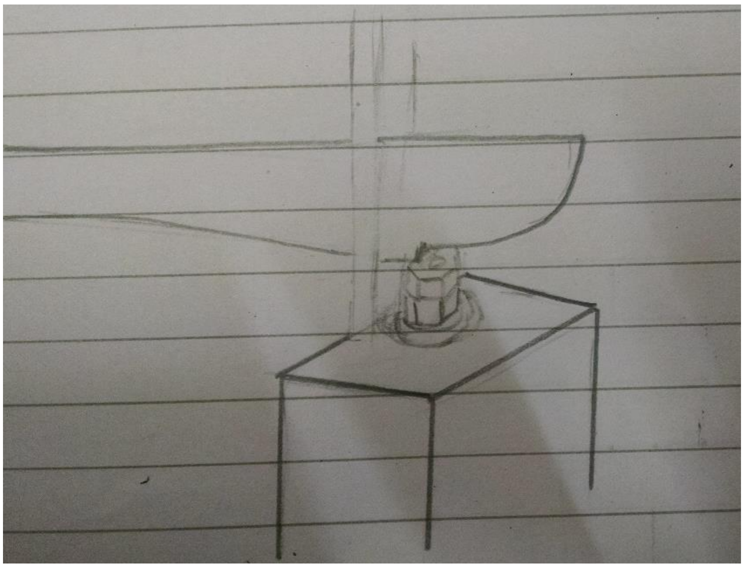

Fig2.4: Sketch of protective guard over the wood at machete impact.

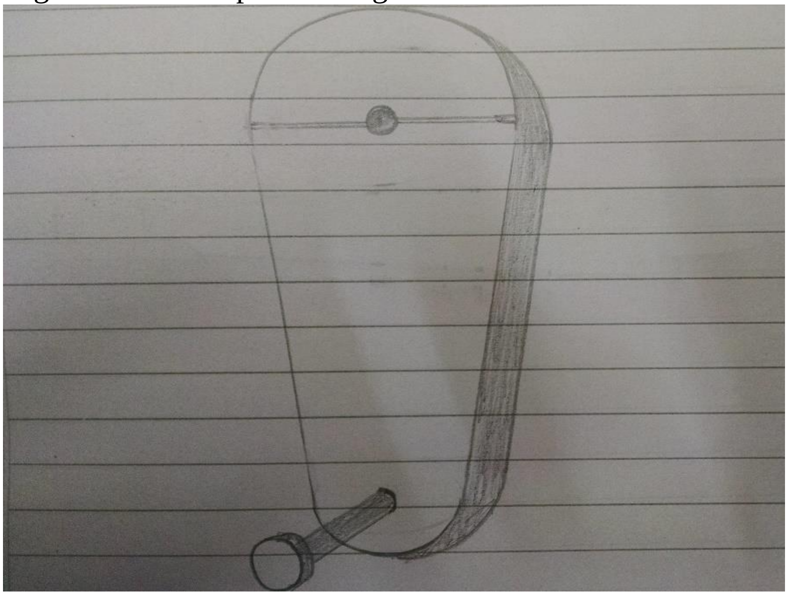

Fig2.5: Rotating Knob for hand rotation of axle.

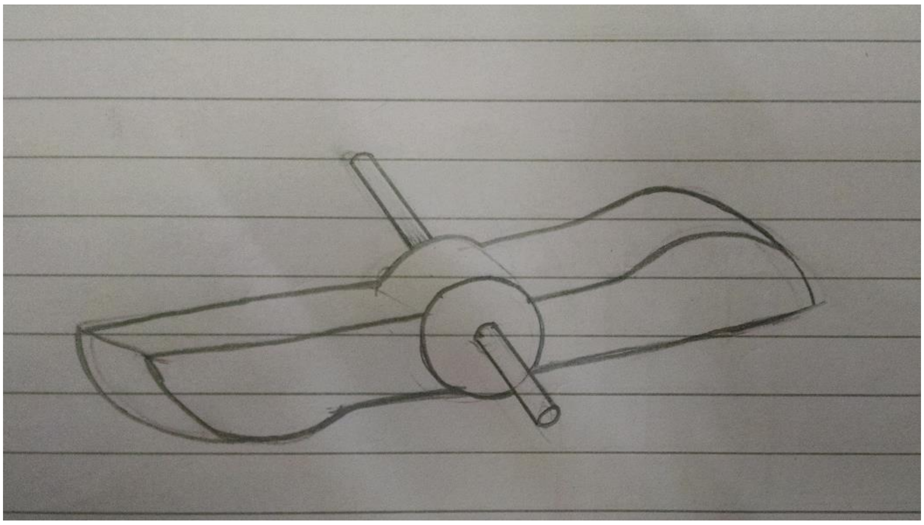

Fig2.6: Axle that moves the machete.

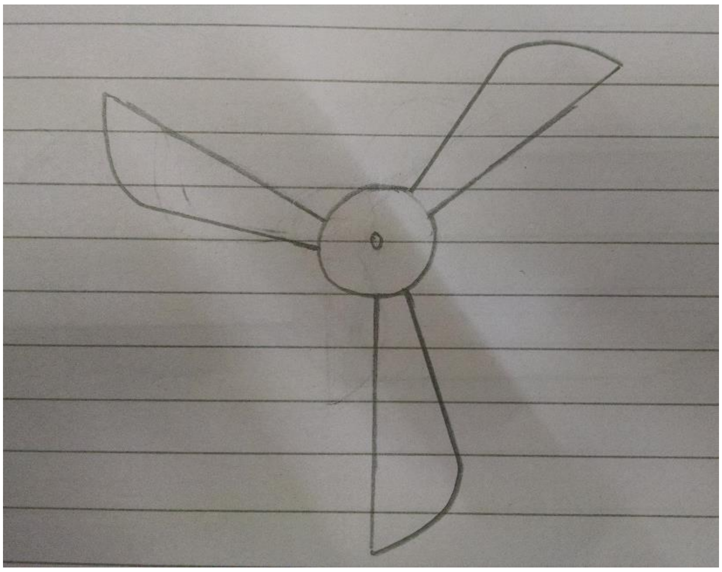

Fig2.7: An optional 3-blade axle for three cuts in one revolution.

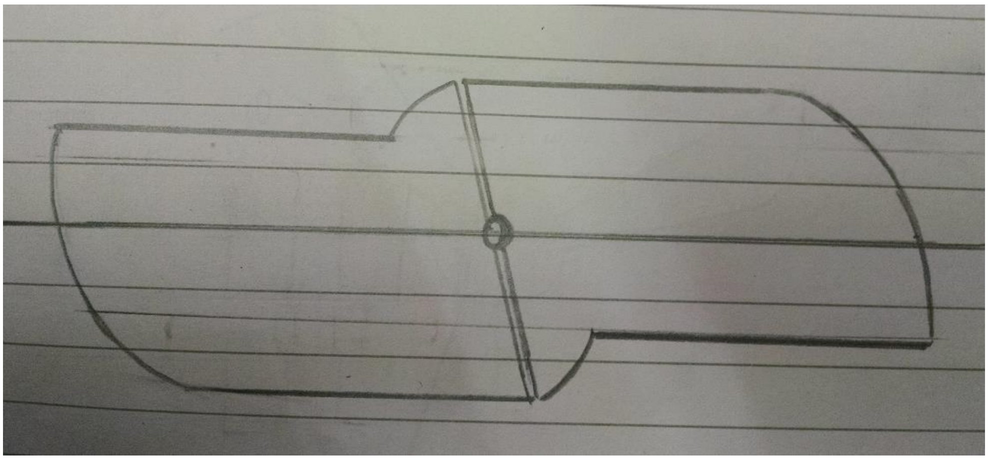

Fig2.8: Centre cross section of the axle.

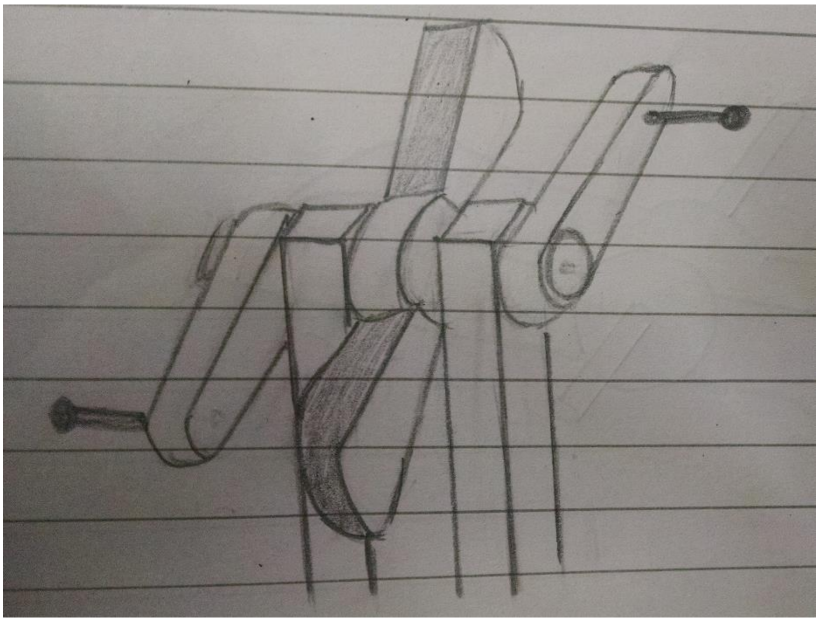

Fig2.9: Axle and Knob assembly.

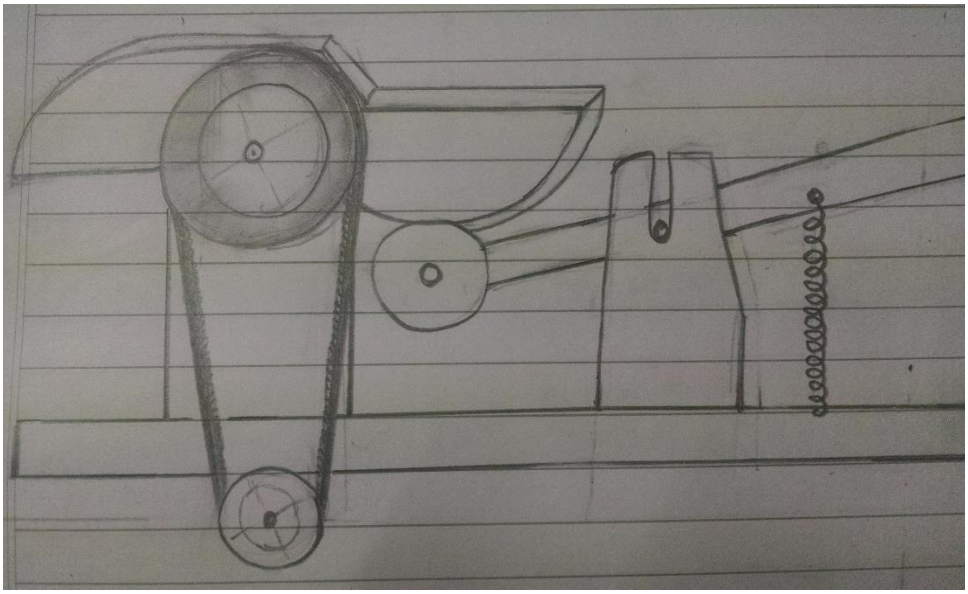

Fig2.10: Use of motor shaft to rotate the axle.

2.4 CAD Model Development

The CAD model of the parts and assembly of some parts was done on CATIA V5 R17. Image of CAD model of some of the parts of the bio-mass chopper is shown below;

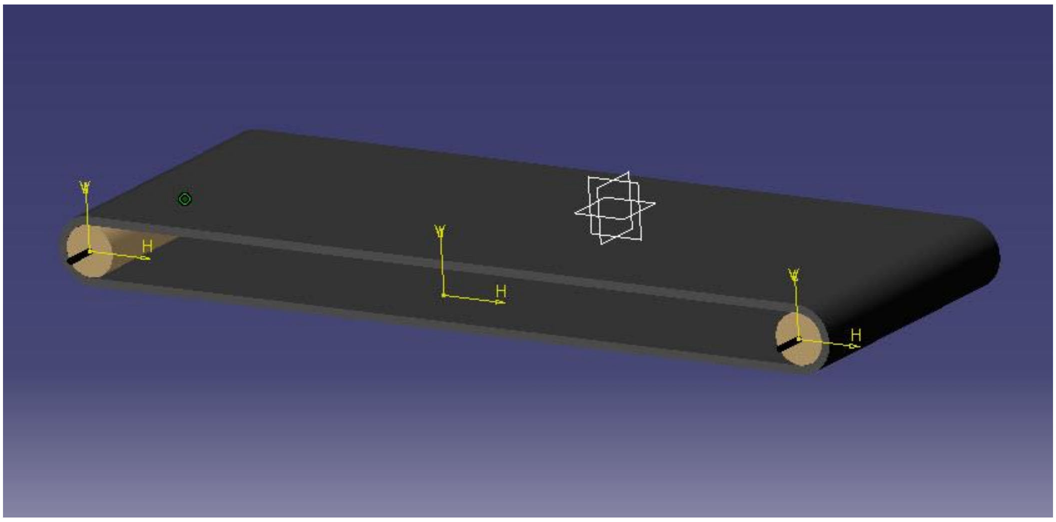

Fig2.11: CAD model of input conveyer belt.

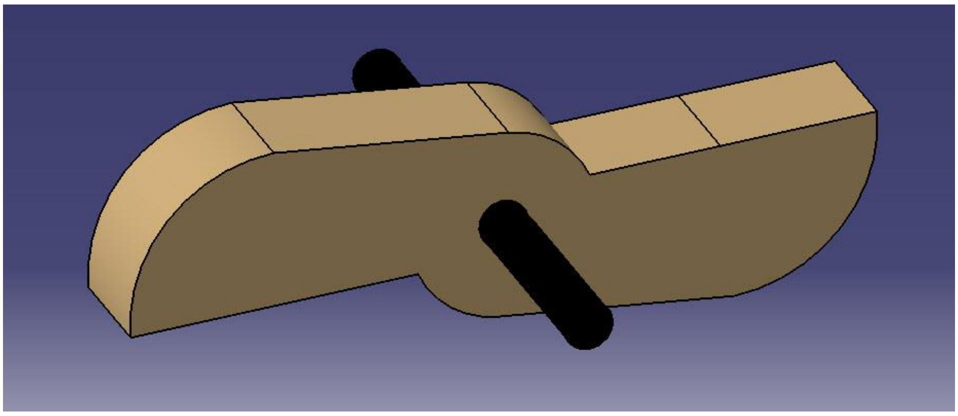

Fig2.12: CAD model of rotating axle and cam pin.

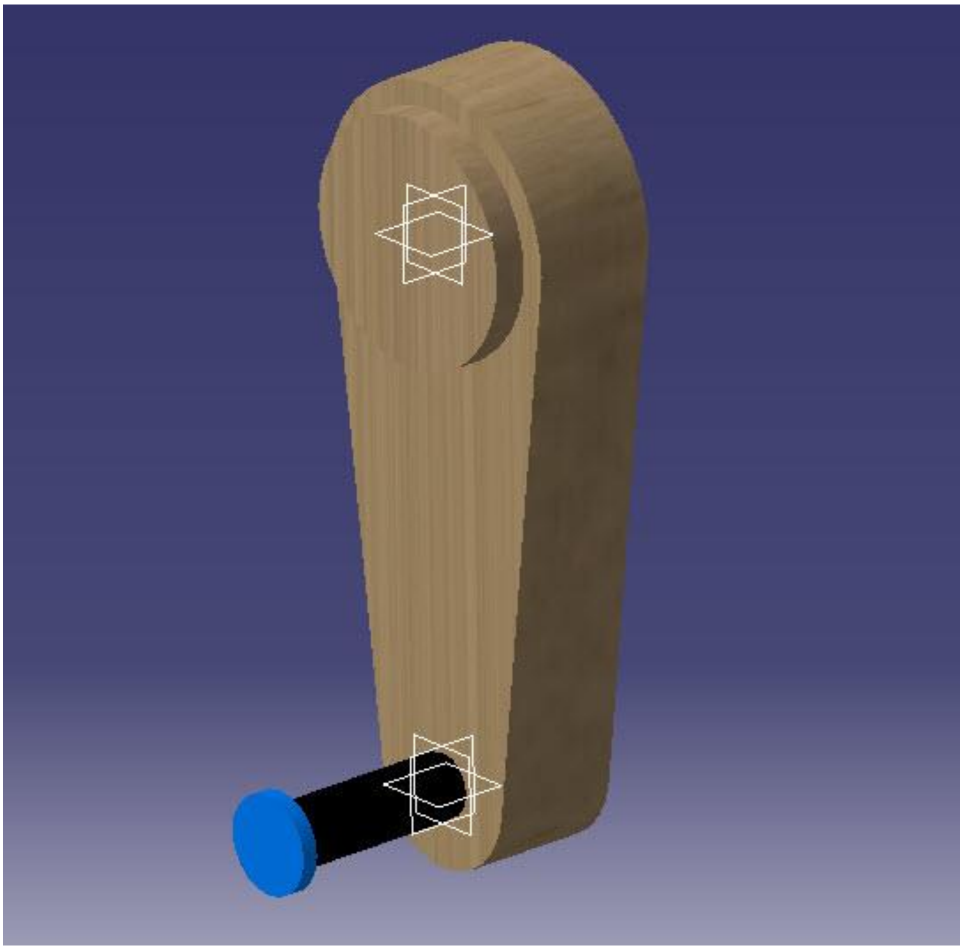

Fig2.13: CAD model of handle for manually rotating the axle.

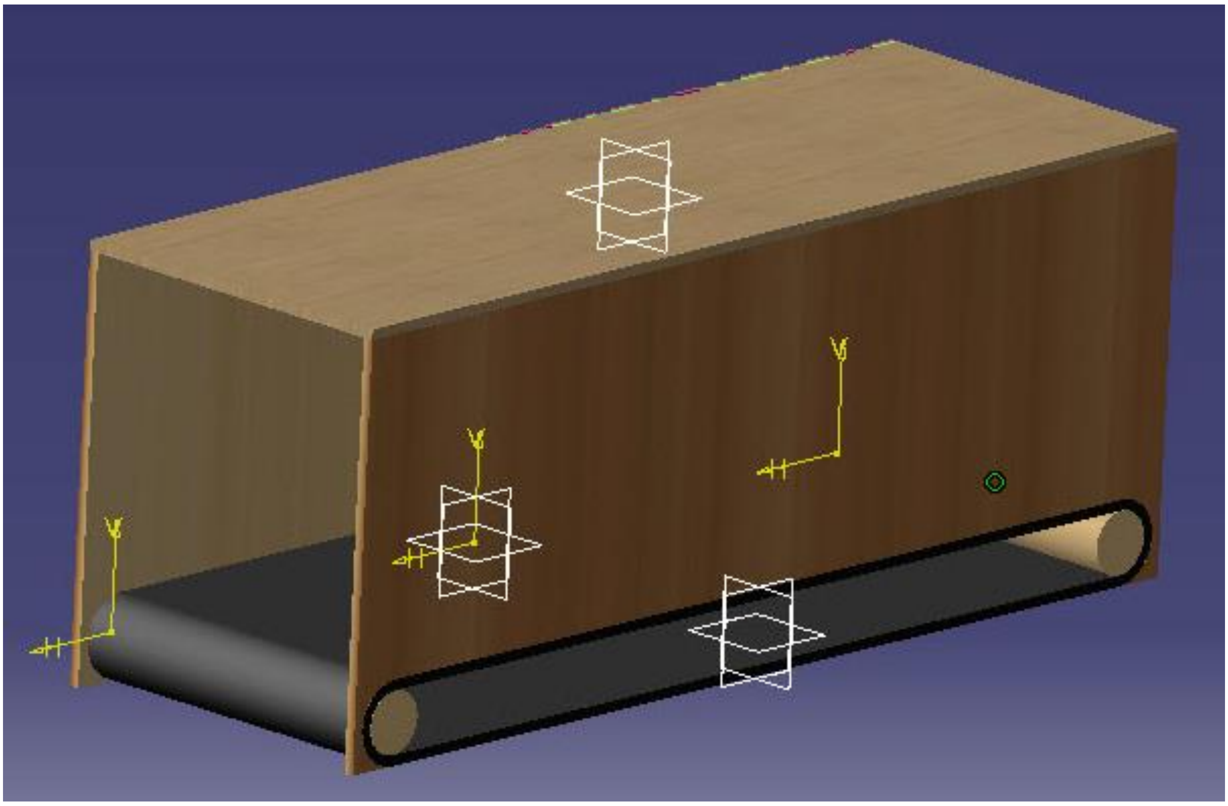

Fig2.14: CAD model of Input area assembly.

Fig2.15: CAD model of rotating axle and handle assembly.

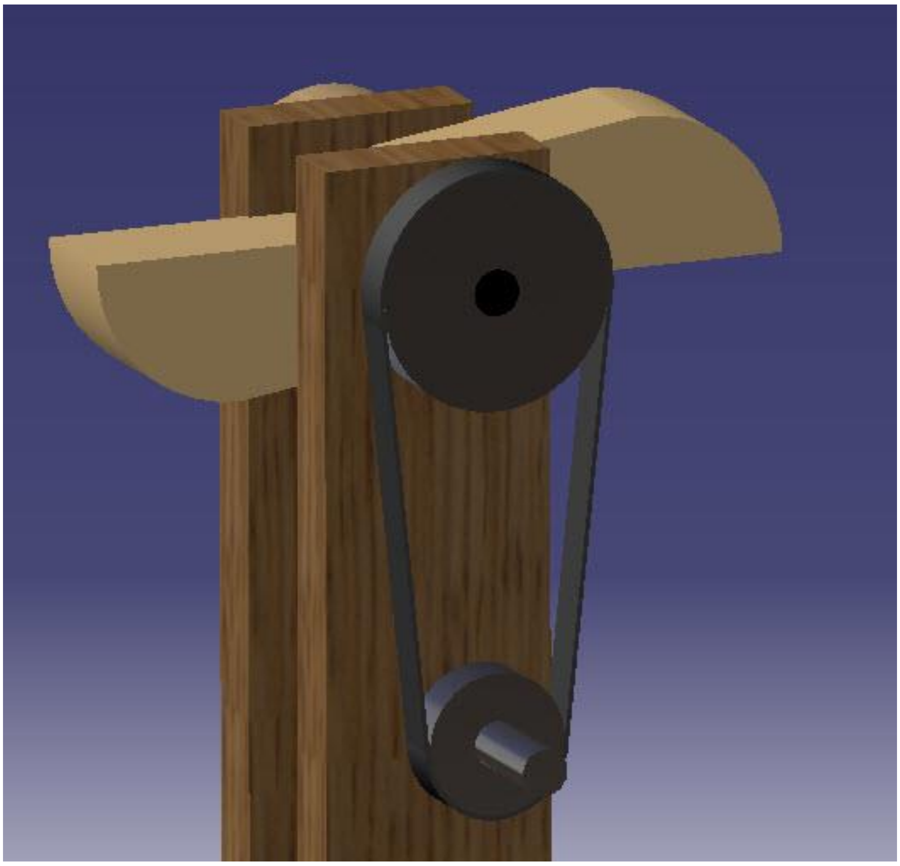

Fig2.16: CAD model of rotating axle and motor shaft assembly.

3. Prototype Development

3.1 Parts Description

The Biomass chopper/cutter was designed to cut both wet and dry biomass and to accomplish a number of goals. The objectives were low-cost, easy to build using mostly hand tools, easy to operate, easy to maintain and requires no welding.

First of all, we breakdown the complete product into various parts for carrying out the prototyping on a part-by-part basis. We can then assemble various parts into smaller sub-assemblies which can finally be assembled to complete the product.

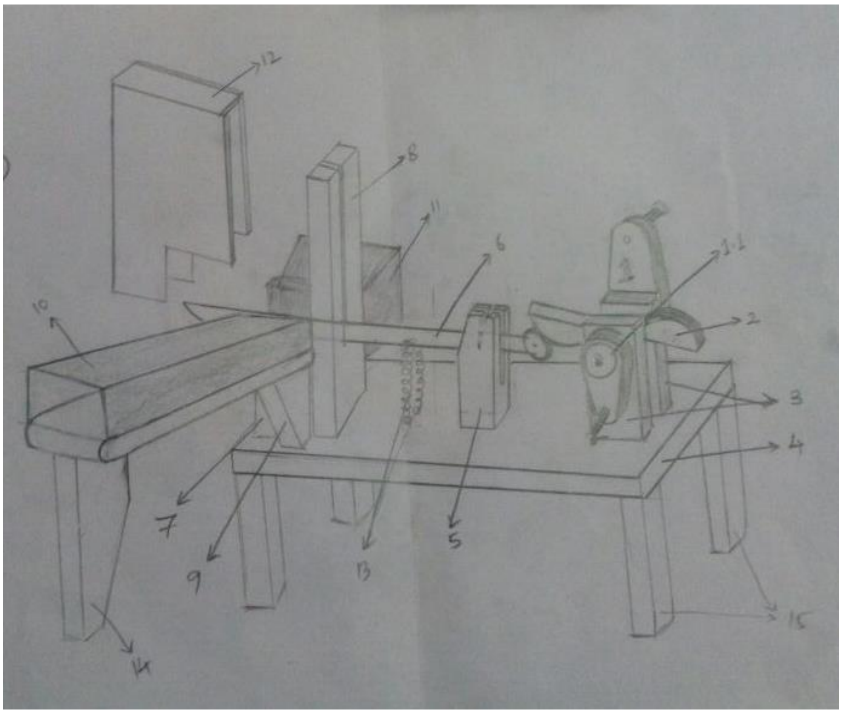

Fig3.1: Part Description of the product

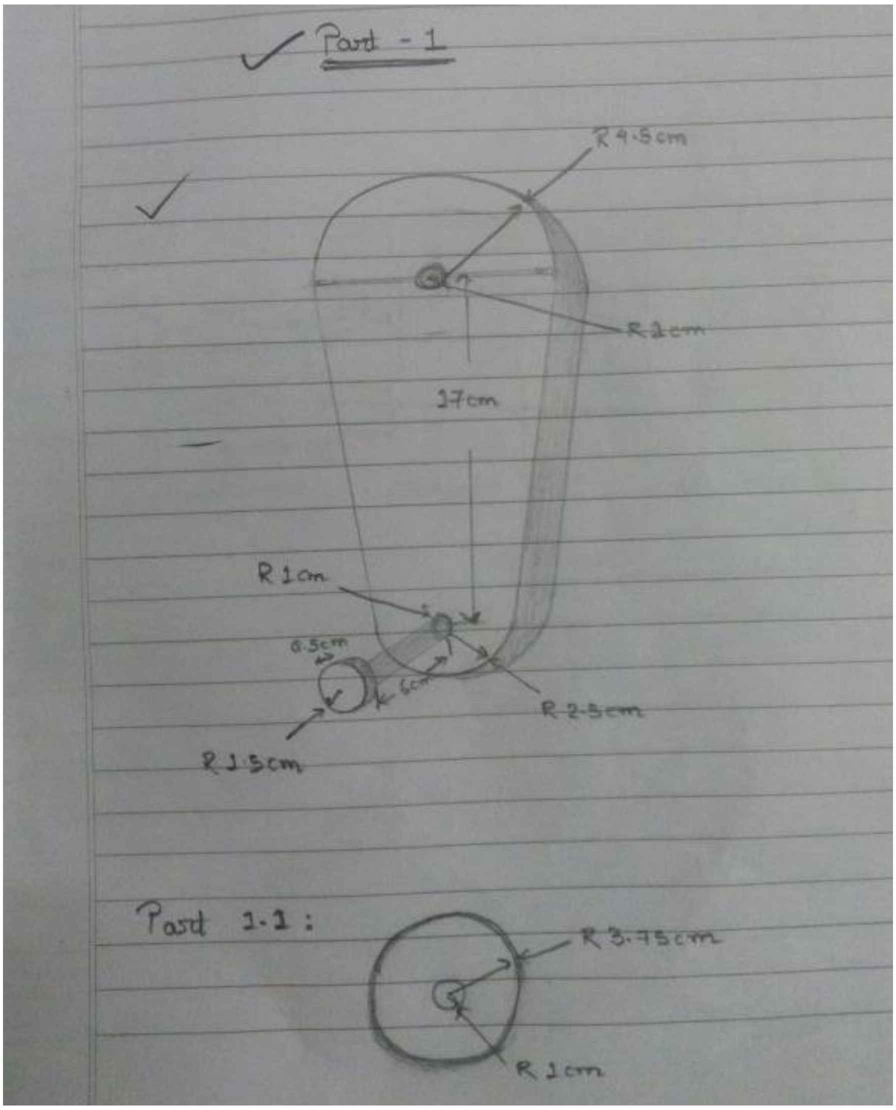

Fig3.2: Part 1 & 1.1-Handle Arm & Knob

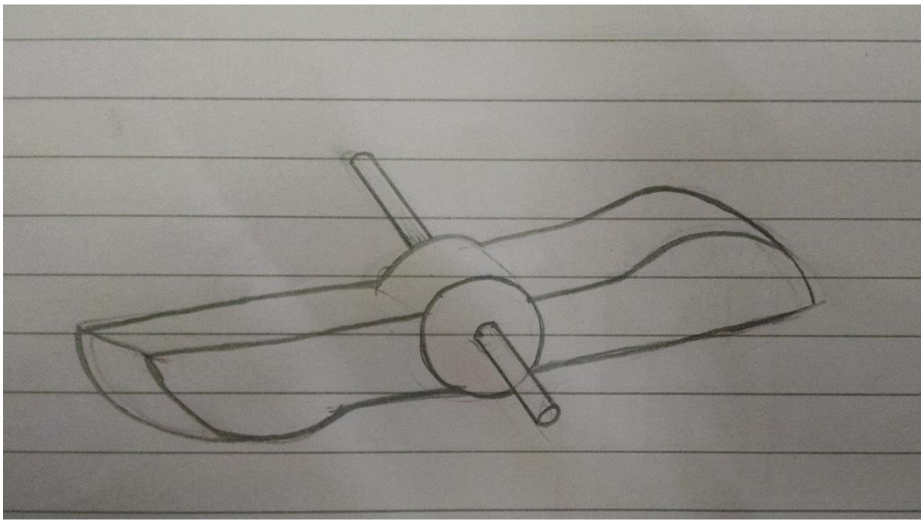

Fig3.3: Part 2-Cam and its Axle

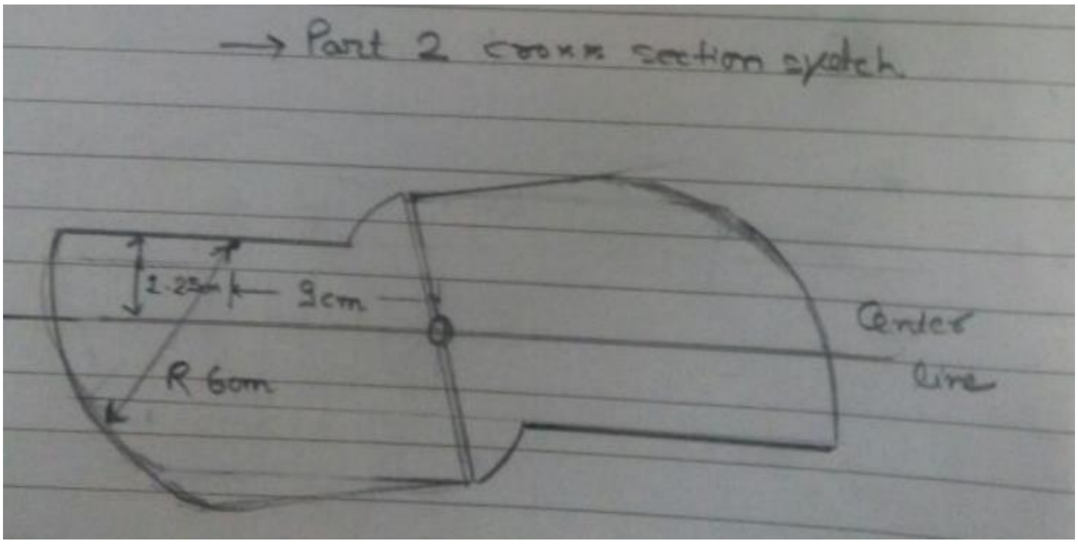

Fig3.4: Part 2-Cam Cross section sketch

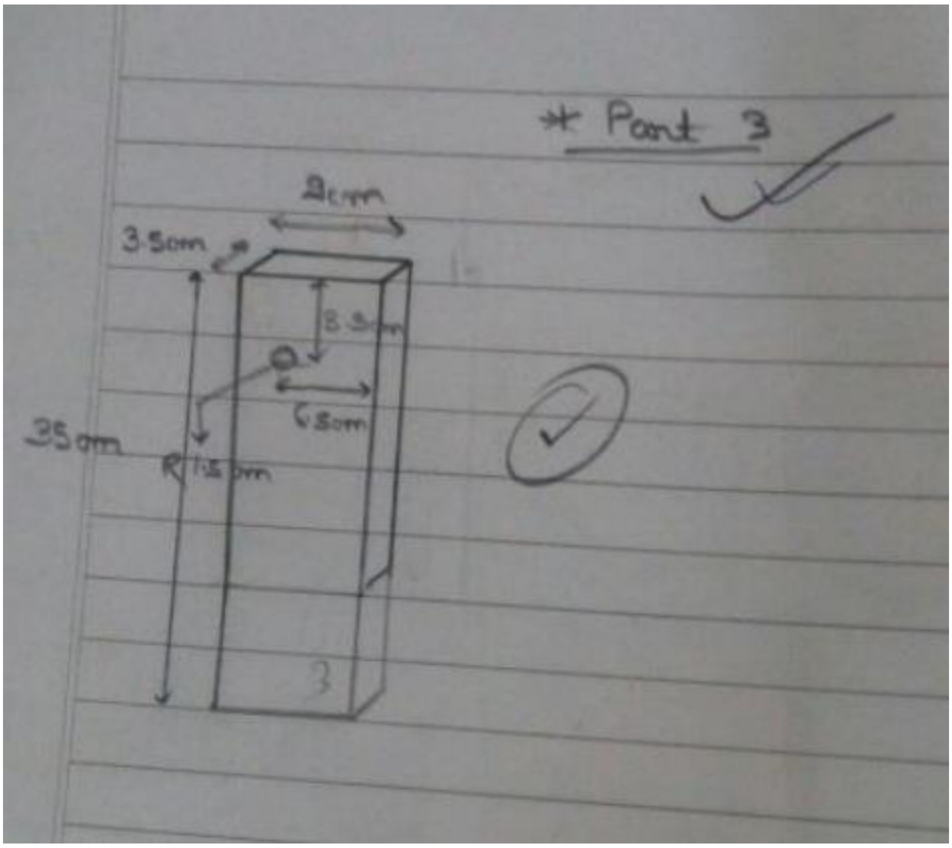

Fig3.5: Part 3-Cam Support Post

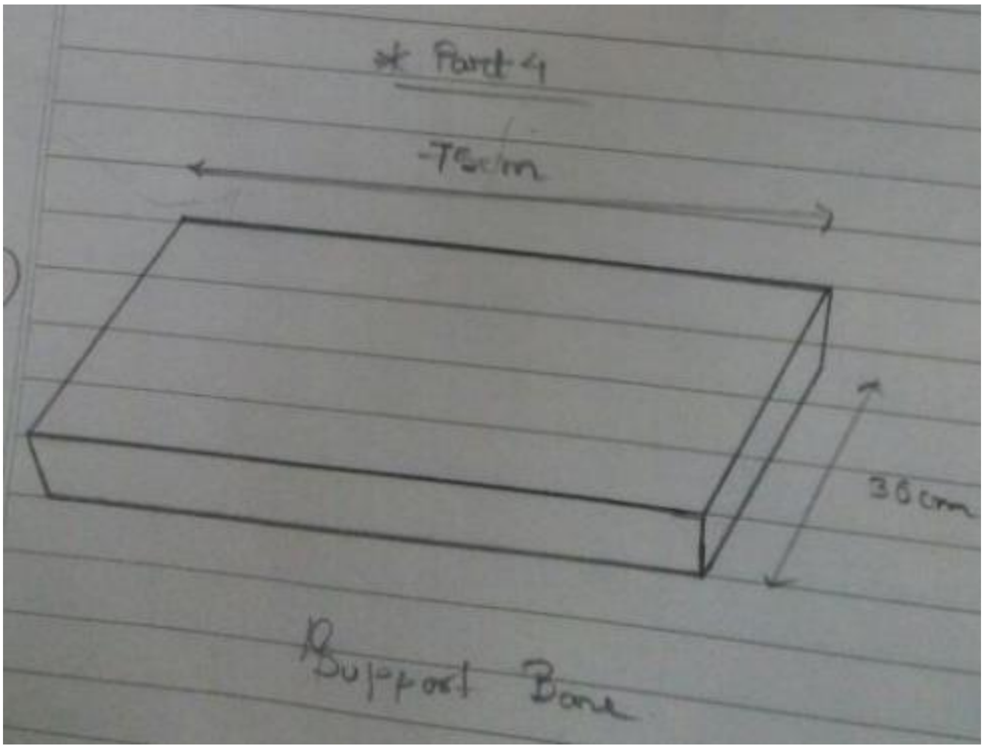

Fig3.6: Part 4-Support Base

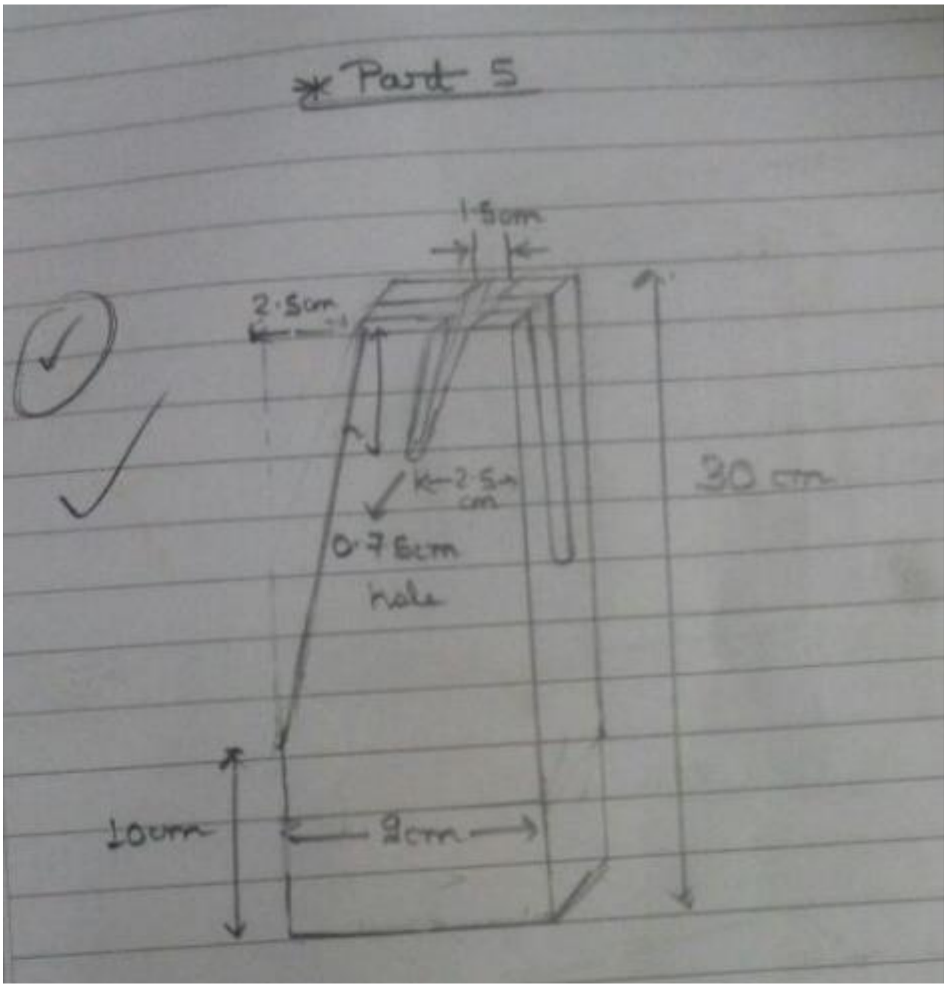

Fig3.7: Part 5-Machete Support Post

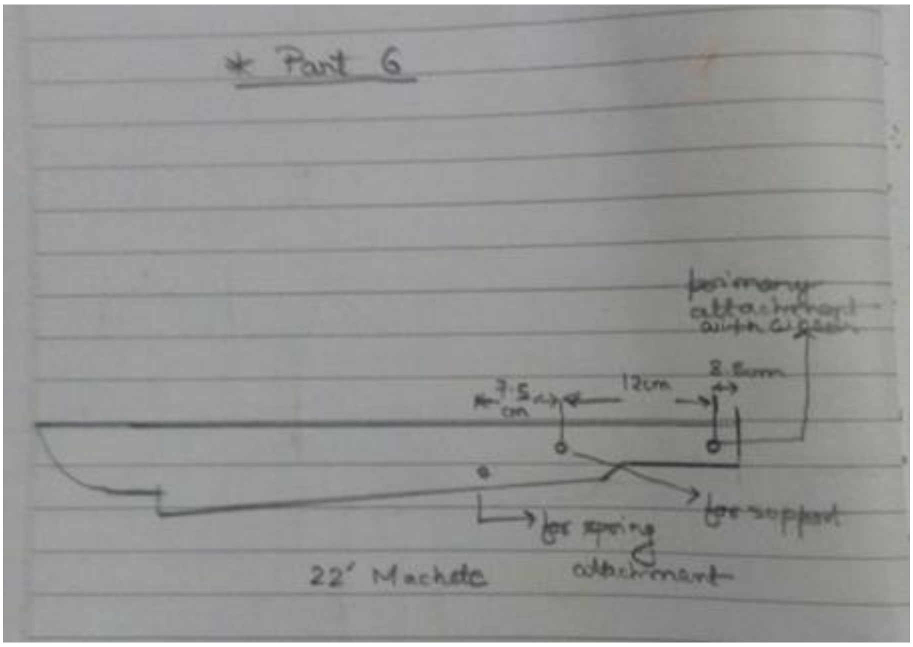

Fig3.8: Part 6-Machete

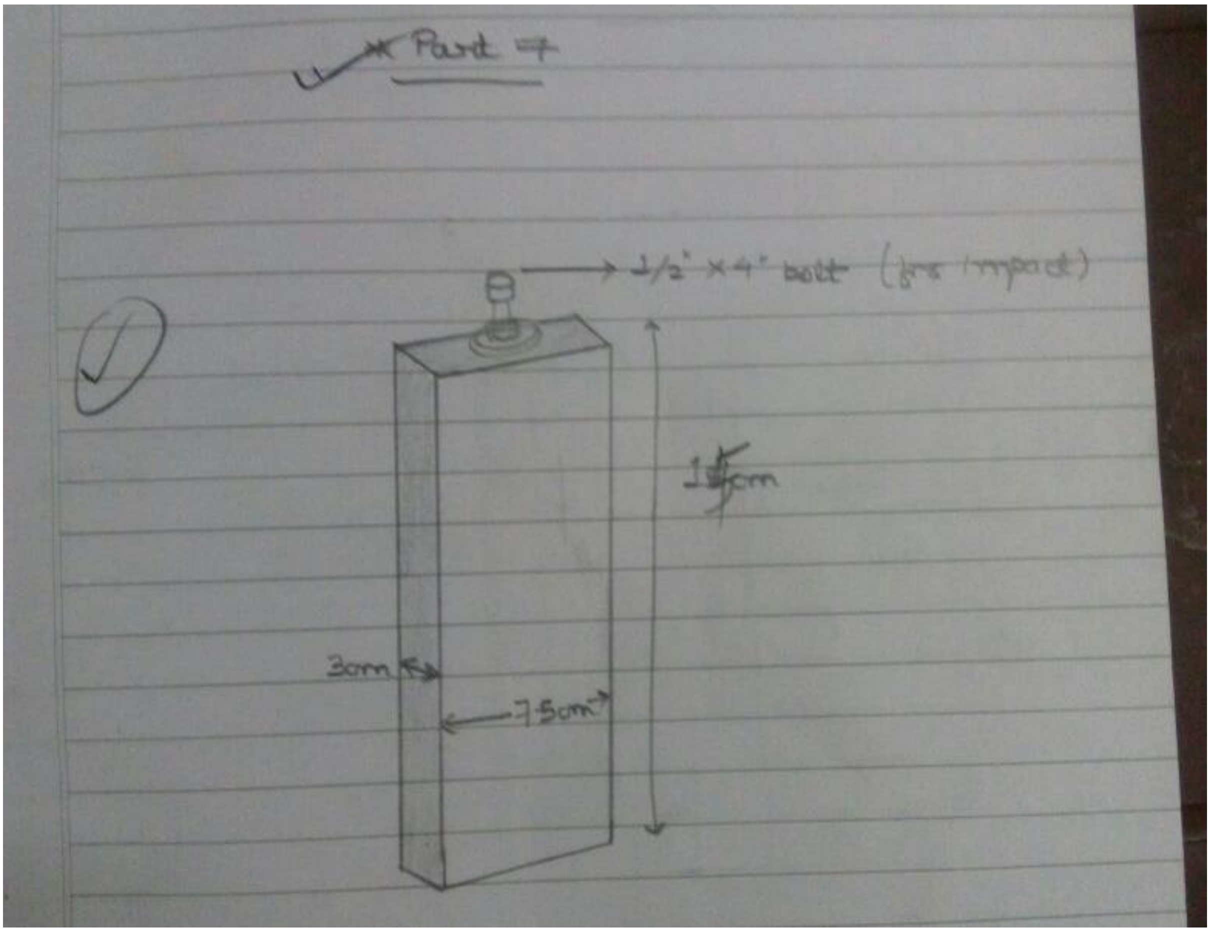

Fig3.9: Part 7-Machete Stop Post

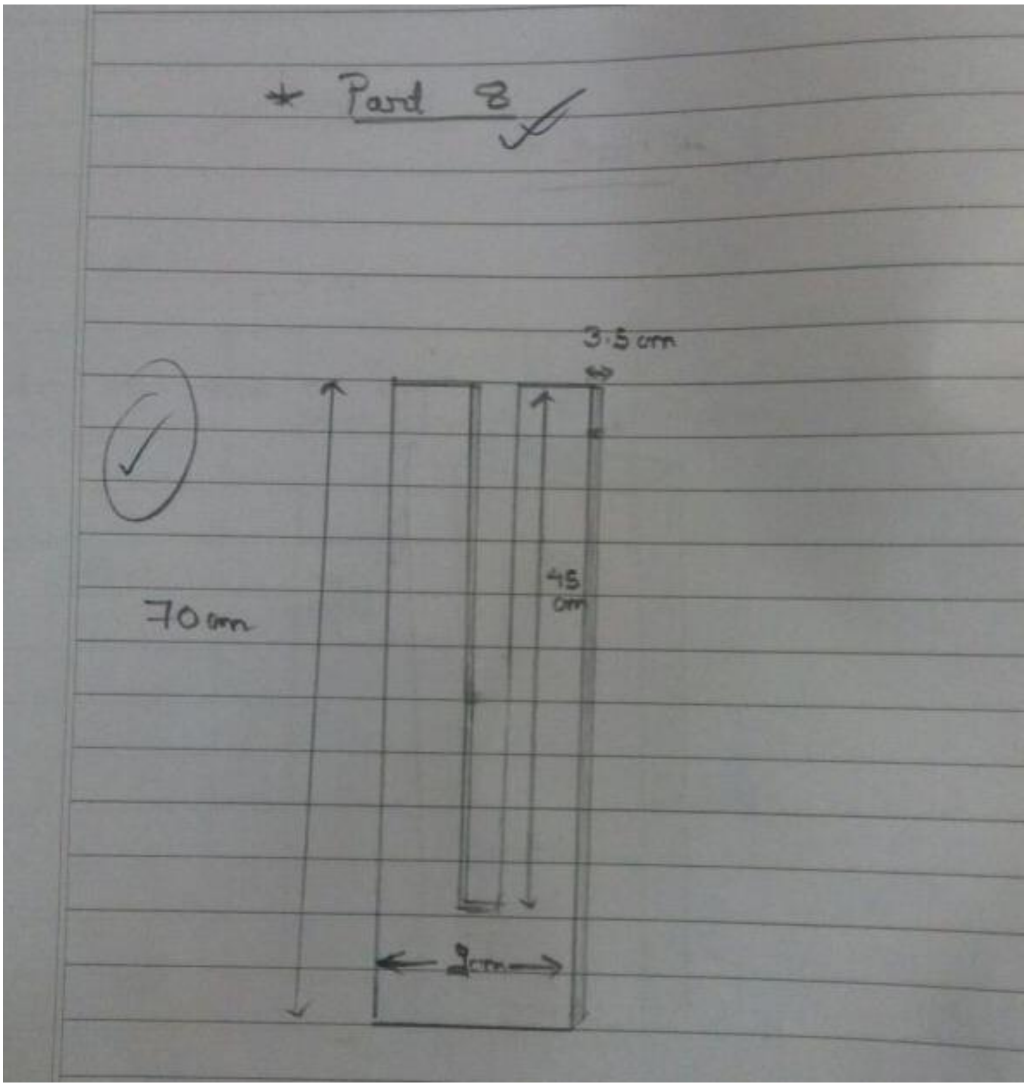

Fig3.10: Part 8-Machete Guide slab

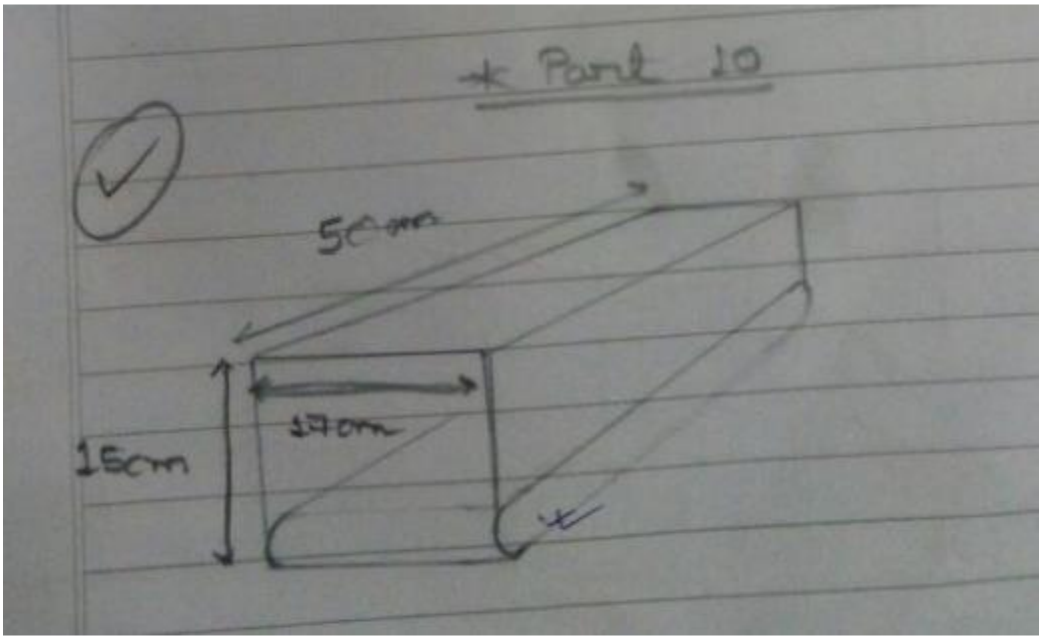

Fig3.11: Part 10-Feed Chute Assembly

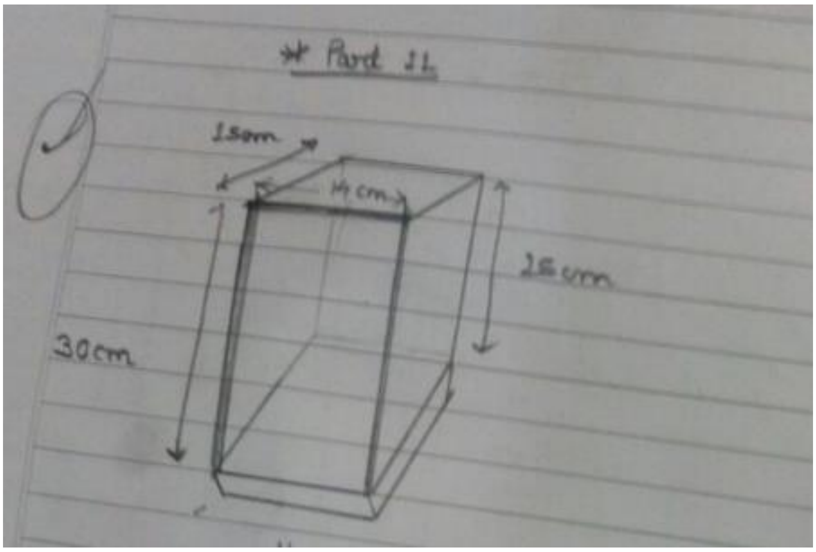

Fig3.12: Part 11- Exit Chute

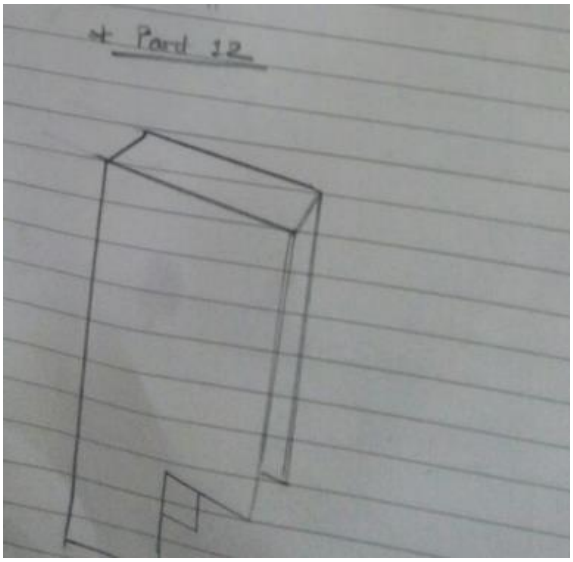

Fig 3.13: Part 12-Machete Guard

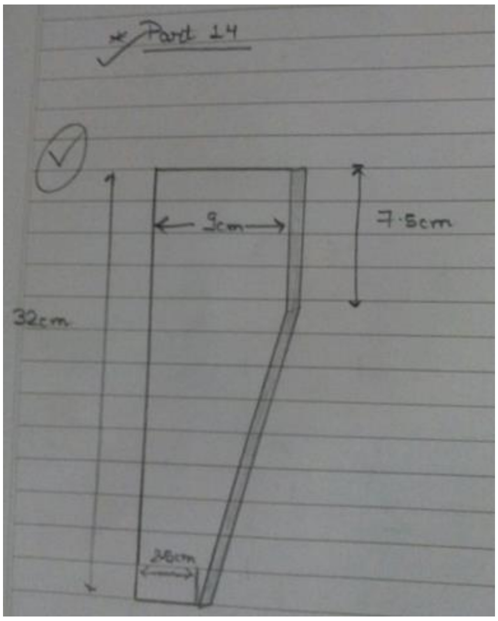

Fig 3.14: Part 14-Feed Chute Support Leg

3.2 Prototyping

Following are the steps and method that should be followed for the construction of the biomass chopper.

- Material Selection: For making the prototype we selected woods of varying quality and strength available in the lab. The dimension of the prototype requires a 3.5” wide * 1.5” thick wood, and a 5.5” * 1.5” thick wood. Hard wood should be used for constructing the chopping section
- Assemble parts first: First of all we will build the individual parts and then assemble them together into the cam section assembly (1-2-3), the exit section (11), the machete assembly (6), the base (15), the feeding section (10) and chopping section assembly (7-9).

Fig 3.15: Part 14-Feed Chute Support Leg

- Cam Section Assembly: It consist of the cam (2), the cam axle (1), and cam support post (3). We used arc welding and screws to hold the cam and handles. The size of screw or nuts can vary as per the drill size. The holes drilled should be properly in order appropriately. We also place thermocol grips on the handle for smooth use.


Fig 3.16: Cam Assembly

- Supporting Rod: First of all we drill a hole at the centre of the cam and then accurately in the two support post. Further we put a metal rod through the support post and cam holes, placing the cam in between the support post, then welding it and tightening the grip of cam on the rod. We should allow some gap between the cam and the support posts.
- Handle (1) and the retention plate (1.1) are then drilled accordingly such that metal rod fits properly and tightly in the hole. It can then be welded with the screws hammered inside the hole for providing the strength required. Handles we built here was circular in shape, however any shape can be used.

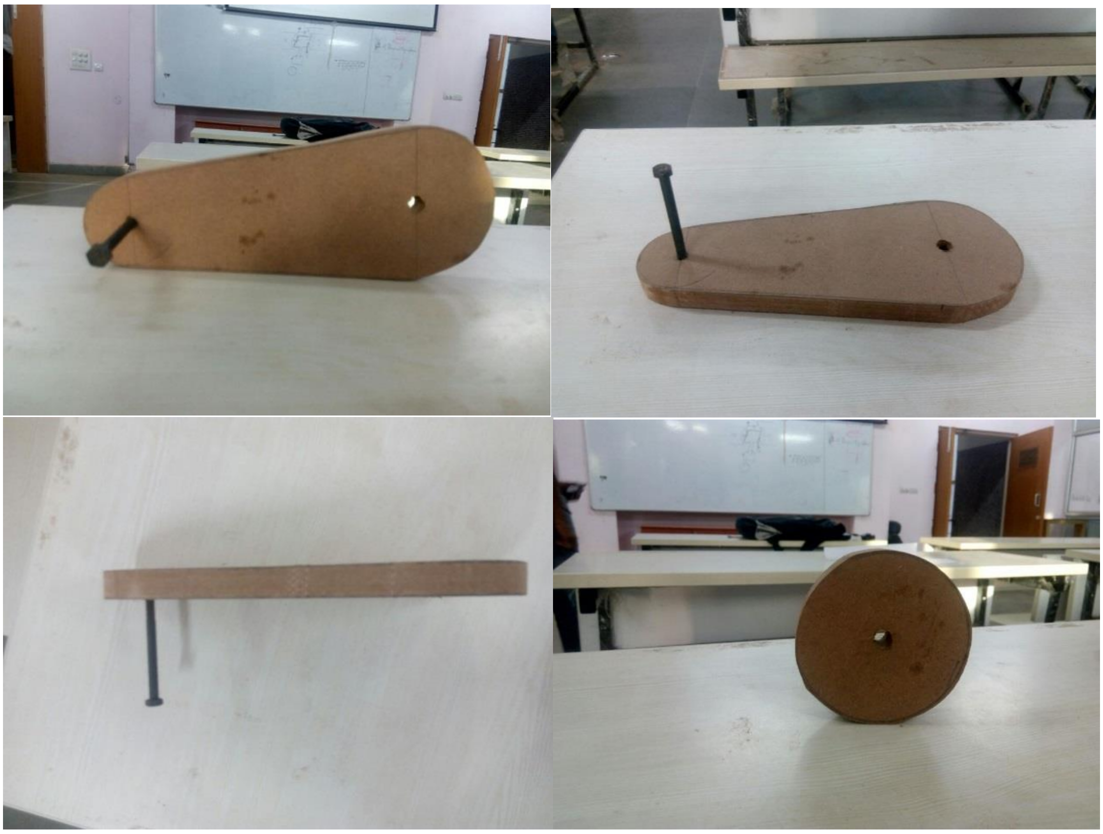

Fig 3.17: Handle Arm

A hole of 7/16” is drilled through the handle at the centre of the circular head so as to hold the supporting rod so that it doesn’t slips during operation. Washers can be used between support post and the handle to leave some gap so that the handle can be rotated smoothly without any glitch or resistance.

- Cam Support Post: It can be made using hardwood so that it would provide a strong bearing surface to the cam axle. However, since the loading on the support post is not much hence even softwood can be used successfully.

  We drill holes in the cam support post at a height of 26.5 cm from the bottom so that the operation can be carried out accordingly. If the hole is not at the correct position the mechanism may not work if the handle gets stuck on the ground ir if enough force is not generated by the cam on the machete.

Fig 3.18: Cam Support Post

- Machete Assembly: Machetes of length 22” or 23” can be used as required for performance test. The design required for the task allows the use of machetes of various length easily. However, the distance between the centers of the roller and pivot bolt should be maintained to be around 5” independent of the length of machete used. The distance between the pivot bolt and the spring supporting bolt should be around 3”.

  The hardness of machete manufactured varies as per the sharpness required. Depending on the hardness, it is easy to drill less hard machetes using a normal metal cutting drill bit, but if they are extremely hard it is not possible to drill them. The hard machetes can further be holed by heating the spot where we want the drill until we obtain a "Cherry Red” colour, it is then left to be cooled. It will result in the portion of metal being softened which can then be drilled easily to make the desired hole. It is necessary that we heat the metal on both the side at the spot and not only on one side by a propane torch.

The pivot bolt is then attached to machete support post (5) and the spring is attached to the base using a nut and then on the machete to the spring support bolt.

It should be taken into care that the bolts at the roller disk pivot or spring portion should not be tightened a lot otherwise the metal in between the nuts and the bolt may weaken due to heavy forces being applied on them during the working of the product.

A hole of diameter ¾” is to be drilled in the machete post at the top so that it can support the nuts which will hold the pivot bolts and then the slot is cut in the machete on the top as required to insert the bolt snugly.

- Machete Roller Disk (6.1): Plywood’s or any thick laminated material can be used to construct the disk 0.5” thick and of required radius. Use of solid wood should be restricted as the force applied on the disk by the cam will be very heavy which will make the roller disk to shatter if it is made up of solid wood. The roller disk are drilled in the centre and joined together with the machete using nut and bolts

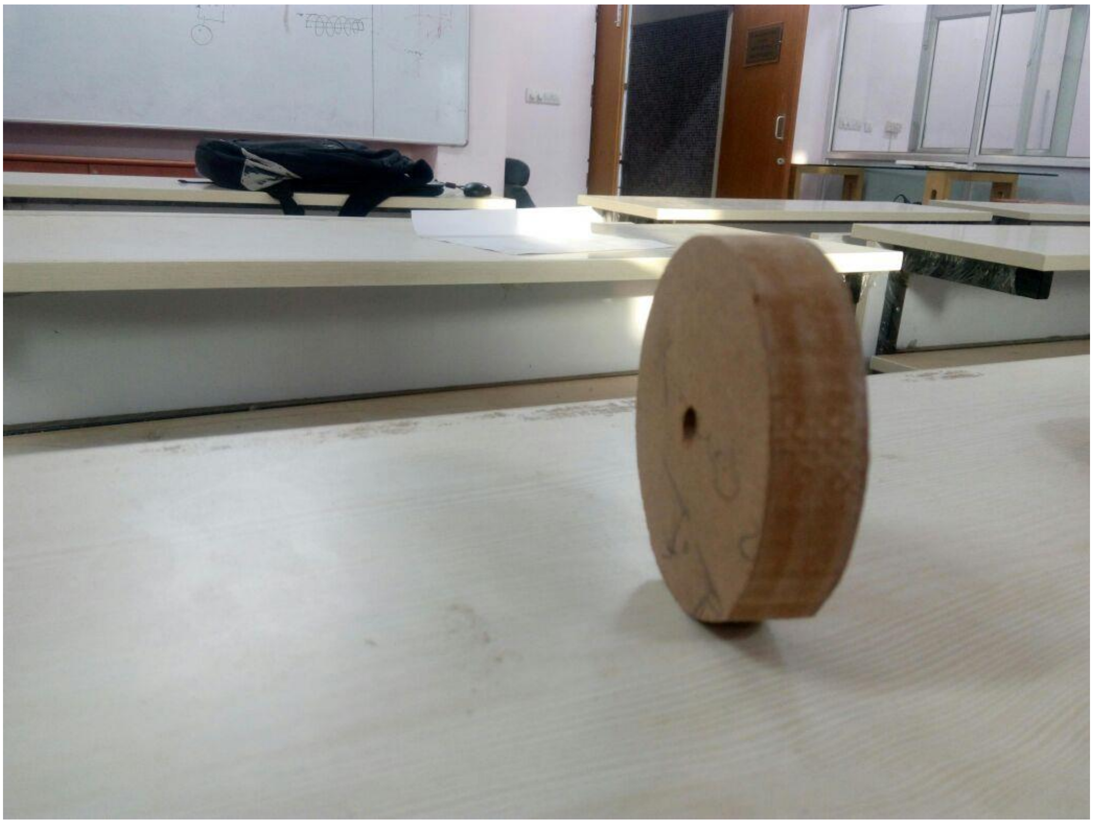

Fig 3.19: Machete roller disk

- Machete stop bolt and supporting wedges (8-9): When the machete falls down on the biomass it generates a great deal of force. It is not possible to let the machete fall on a wooden surface as it will cut it simultaneously after every hit. Hence it is necessary that we use a stop bolt to withstand the pounding forces from the machete. Since the bolt will be subjected to heavy pounding forces 0.5” size bolt will be appropriate for the job. The threading in the wood for the bolt is deliberately undersized to be around 7/16” so that it can be forced into the supporting wedges. A washer can also be used to ensure that the bolt does not creep down into the post due to the force implied on it. We can use double nut to be assured that the two bolts will remain accurately adjusted.

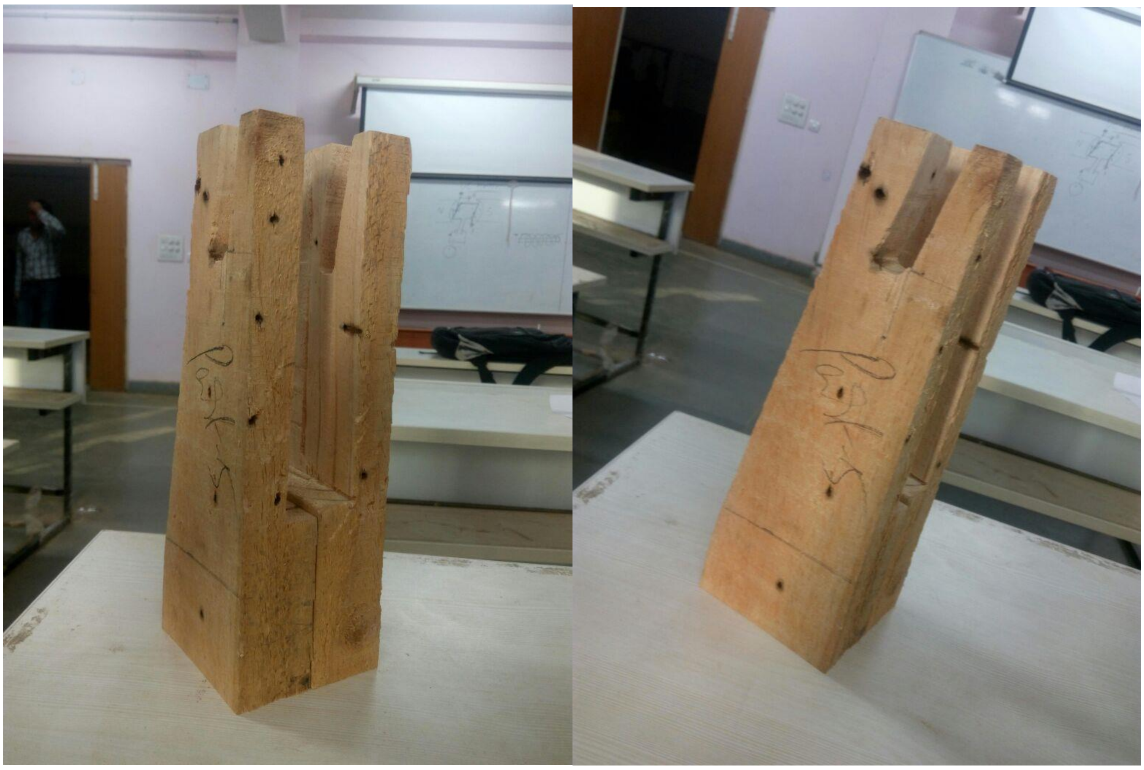

Fig 3.20: Machete support post

Fig 3.21: Machete guide slab

Fig 3.22: Machete stop bolt

- Feeding Section (10): The slabs of the feeding section can be pre-assembled though leaving the top open the feeding section is assembled to the main product. It will help in installing the screws that we will hammer to hold the section to the chopper, and to hold the front leg of the feeding section.

Fig 3.23: Feed Section Assembly

- Exit Section (11): Here also we can assemble the slabs of the exit section initially. The slabs can be attached together using wood screws or fevicol. To remove the chopping section (9) or to replace the support bolt we should first remove the exit section to allow easy access to them.

Fig 3.24: Exit Section

- Safety Shield (12): The Machete Safety shield can be made using a frame from ½” * 1/3” wood frame and the sides of the shield can be made using wood or even metal. The shield should be made such that it slips gently over the machete guide post.
- Chopping Block (9): While constructing the chopping wood it should be ensured that the wood grain is parallel and not cross grain to the surface of the machete used resulting in a maximum lift. The chopping wood is provided with four cutting surfaces so that if there is any damage to on surface it can be removed, rotated 90 degree and reinstalled. The chopping wood (9) can be removed by first removing the exit section so as to gain easy access.
- Installation of Cam Assembly: First of all we should draw the base of the two support posts on the base section then the cam assembly is placed on the base section at the end of the base section and centered from both the sides. We can use adhesives such

as fevicol for gluing the cam assembly on the base section.

- Installation of Machete Assembly: After installing the cam assembly we then install the machete assembly. The machete support post which is attached to the base section at a required distance such that the rotating cam will be centered to the roller disk at the end of the machete. Again we can use pencil to draw accurately the positioning of the machete support post on the base section. The machete assembly is the installed by putting the pivot bolt inside the slot cut in the machete support post so that the bolt fits the slot snugly and can be tightened using nuts. The spring is then installed on the base section by attaching a screw on the base section to hold one end of the spring tightly. The other end is then attached to string support bolt, taking care that the nuts are not over-torqued
- Installing Chopping Section Assembly (8-9): After the machete assembly is installed in the machete support post, the chopping section assembly, is positioned so that the machete strikes the chopping section in the flat portion before it curves upward again. The accurate position is observed and the chopping wedge is installed. It should be ensured that the machete is located at the centre of the machete guide post so that the operation is smooth and easy. The end shape of the machete can be varied considerably. The stop bolt installed on the chopping block is implied to tremendous force and if the end of the machete is extremely sharp it can even cut the stop bolt's head. The area of impact of the machete should be checked for a number of times before finally assembling the chopping section onto the base section.

Fig 3.25: Exit and Feed Section Assembly

- Machete Safety (12): Since the edges of the machete are extremely sharp it is essential to take care while operating the machine. The portion of the machete which would not be used for the cutting purpose can be dulled so as to reduce their sharpness in order to reduce the danger to the user. It is also equally important to keep the safety shield on during the cutting operation.
- The spring of appropriate tension and length should be selected so that a minimum required force is generated and also there should not be overloading on the cam due to high tension springs.
- The screw that holds the bottom end of the spring shall be positioned accurately so that the movement of the springs is smooth and does not tangle up with any other part on the base section.
- The axles, the top of support post as well as the roller disks and all other nut bolts can be lubricated using oil so as to reduce friction.

Fig 3.26: Final Completed Prototype

4. Discussion

4.1 Merits:

The biomass chopper that we intend to design basically, taking general rural people into consideration as our target user. Hence it should be a low cost model with the following desired properties;

- It can be used to cut wet as well as dry biomass
- The machine built is quite economical
- The procedures to build the machine are very simple
- Easy to maintain.
- It can be operated easily by man and woman with equal efficiency
- There is no need of extensive machining or high amount of welding
- Can be conveniently used by women and children (doesn't require much strength to operate).

4.2 Future Scope: Works To Be Done.

- ✓ The physical model is then to be evaluated for its functioning and usability as well as the safety in using the machine.
- ✓ The machine can be operated automatically using an electric motor. One of the handles can be detached and replaced with a pulley or chain sprocket. The rotation speed of the chopper should be maintained between 60 to 90 rpm so as to achieve optimum cutting.
- ✓ Depending on the particular use of the chopper one may need to install or fasten the chopper securely to a solid structure like a table top, especially if it is operated automatically using a motor.
- ✓ It will be better to coat the feed section and exit section with a light oil or moisture protection substance

5. Conclusion

The concept of the product was developed and modified following the needs of the rural people and suggestion from the operators of existing machine. The initial sketches were developed and the product was aimed at keeping the mechanism simple and easy to operate by anyone.

The completed CAD model of the product is to be made and analysed. Finally, a complete physical model of the machine will be made using the appropriate material and will be evaluated for its functioning, usability, ergonomics, aesthetics, safety etc. The product can easily overcome most of the difficulty faced while operating the existing models.

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